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Incidence of WHITE PINE BLISTER RUST INFECTION *in the Lake States*

by D. B. King

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INCIDENCE OF WHITE PINE BLISTER RUST INFECTION IN THE LAKE STATES[1/]

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INTRODUCTION

This is an interim report on one phase of a comprehensive analysis of the economics of eastern white pine (*Pinus strobus* L.) production, the objective of which is to determine to what extent and on what particular areas in the Lake States application of special protection and management measures for growing white pine can be economically justified. Control of white pine blister rust is one of the alternatives considered in this analysis.

White pine blister rust, the most serious disease of white pine, is caused by growth of a parasitic fungus (*Cronartium ribicola* Fischer) which spreads alternately from white pines to currant and gooseberry plants, collectively called *Ribes*, and from the ribes to the pines. The disease is carried by means of airborne spores produced throughout the growing season. It cannot spread directly from one pine tree to another.

The disease is believed to have originated in Asia and then to have spread westward into Europe where it was first reported in 1854. In North America it was first reported in 1909 on white pines in New York; by 1915 it was noted in Wisconsin. Today blister rust is well established throughout the Lake States, as well as in other areas from coast to coast, and causes substantial mortality in unprotected young white pine stands. Local control efforts aim to destroy all ribes plants within infecting distance of white pine stands (i.e., up to about 900 feet depending mainly on density of cover), thus interrupting the life cycle of the disease.

1/ A contribution of the following offices of the Forest Service, U. S. Department of Agriculture: Division of Forest Economics Research, Washington office; the Division of Forest Pest Control, North Central Region; and the Lake States Forest Experiment Station. The Lake States Station is maintained at St. Paul 1, Minn., in cooperation with the University of Minnesota.

2/ Assistant Director, Division of Forest Economics Research, Forest Service, U. S. Department of Agriculture, Washington 25, D. C.

The magnitude of losses caused by blister rust in unprotected white pine stands, and the volume of pine that could be "saved" by rust control measures, must be considered in planning management of white pine stands. Quantitative estimates of probable white pine losses without rust control under various combinations of site, stocking, and hazard conditions have been unavailable. To obtain such data a special rust infection incidence survey of Minnesota, Wisconsin, and Michigan was conducted by the Forest Service in the fall of 1956.[3/]

SURVEY DESIGN AND PROCEDURES

The rust infection incidence survey involved field sampling of more than 500 randomly selected white pine plots to determine the relationship between ribes population and proportion of pines, by diameter classes, receiving fatal rust infection in specified years.

Sample plots were randomly selected in areas given ribes eradication treatment since 1952. When a pine area is treated, essentially all ribes bushes are destroyed and the number removed is recorded. Ribes populations per acre, at time of treatment, on areas surrounding sample plots were computed from these ribes eradication records. Thus for each plot, general ribes population at the time of working the area could be correlated with the rate of fatal rust infection originating during years immediately preceding eradication treatment. This eradication treatment was the first on about two-thirds of all areas examined, while the remaining third had been previously treated one or more times. The plot data collected therefore provide some comparisons of conditions on untreated areas and areas previously treated but not under control.

Each plot measured covered an area of 0.3 acre and consisted of three parallel strips one-half chain apart, five chains long, and 13.2 feet wide. The total number of pines and the proportion fatally infected by diameter class and by year of infection origin were determined for each plot. To smooth fluctuations in annual rates, the average number of pines fatally infected during a 5-year period was determined for each diameter class of pine. Rust infections must develop for several years before they become readily recognizable. To prevent failure in recognizing infections, a 4-year development period was therefore

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3/ Fieldwork was conducted by Area and District Leaders of the Division of Forest Pest Control, North Central Region, Forest Service, U.S.D.A. The survey was designed and results analyzed by the Division of Forest Economics Research, Washington office, with cooperation of the Lake States Forest Experiment Station and the Washington office Divisions of Forest Disease Research and Forest Pest Control.

allowed by tallying fatal infections that originated from 4 to 9 years prior to the survey apart from all earlier or later infections.

Variations in incidence of rust infections originating from year to year and the relationship of these variations to weather conditions were also determined.

Data presented in this report pertain to the three Lake States. Although some white pine and blister rust are present in adjoining States, data from this survey indicate that rates of pine infection in these adjoining States are negligible. Thus examination of 1,167 pines on 54 sample strips in Ohio, for example, failed to disclose any fatal infections.

SURVEY RESULTS

In this analysis, the Lake States region was divided into three general zones of high, medium, and low hazard extending generally from east to west (fig. 1) on the basis of variations in rust hazard recognized by the Division of Forest Pest Control with adjustments indicated by survey findings.

Incidence of rust infection

Survey results supported the concensus of blister rust specialists that rust hazard in the Lake States is greatest in the North and diminishes southward. The percentage of white pines fatally infected varied among hazard zones and among States in each hazard zone.

Within each of the general hazard zones, infection incidence varies considerably among localities. In the high hazard zone of northern Wisconsin, for example, the proportion of pines fatally infected generally varied among plots from 0 to 20 percent, with occasional plots as high as 44 percent. Local variations are attributed to a number of factors including direction and velocity of wind currents, amount of rainfall, density of forest cover, elevation, species and height of ribes, temperature, topography, and prevalence of fog.

Research is under way to determine the relationships between rust hazard and such local microclimatic conditions. Improved knowledge of these relationships will some day greatly increase the efficiency of rust control work by making possible more precise determinations of the degree of hazard in local areas. Lack of such information at

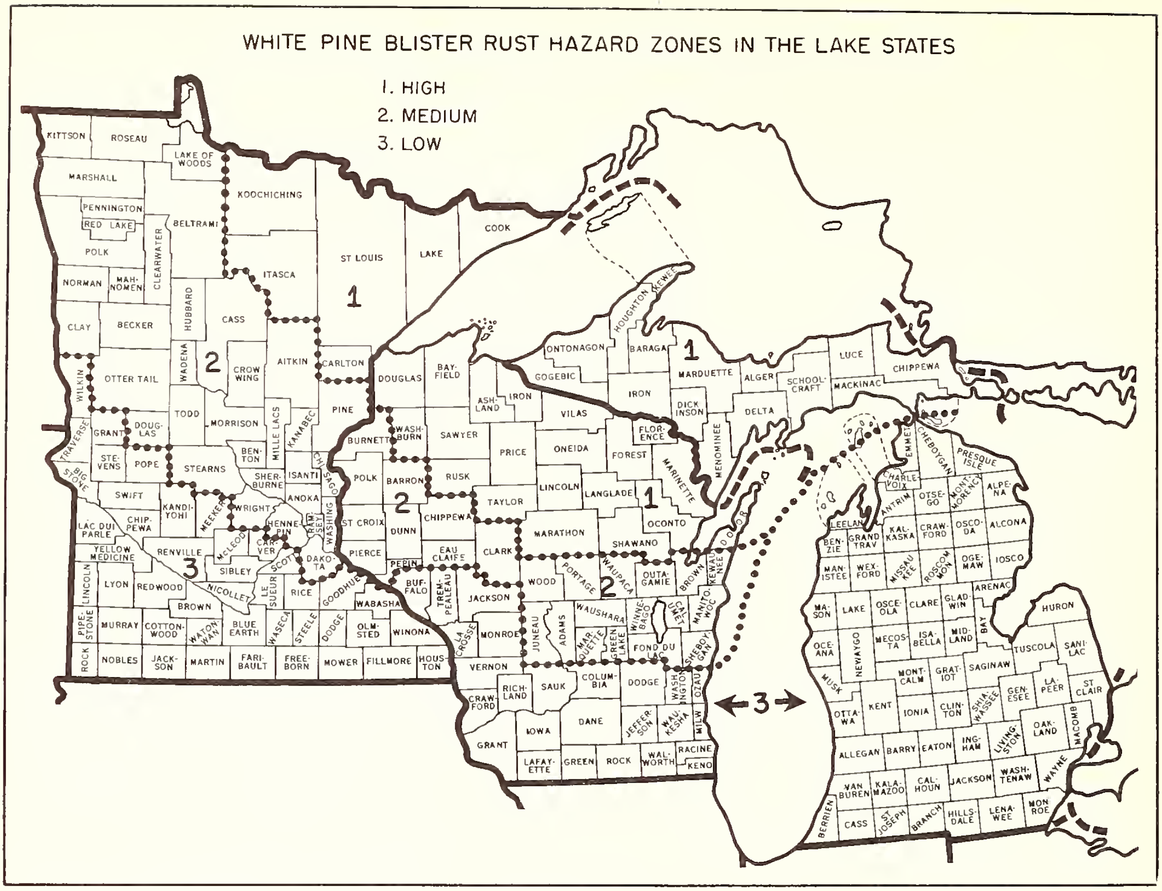

Figure 1.--Rust hazard in the Lake States generally is greatest in the North and diminishes southward.

present made necessary the development and use of average estimates of rust incidence that can be applied generally to each zone.

For the region as a whole, 4.2 percent of almost 46,000 pines examined were fatally infected. The proportion ranged from almost 13 percent in the high hazard zone in northern Minnesota to 0.3 percent in the low hazard zone in Lower Michigan (table 1). It averaged 9.2 percent in the entire high hazard zone, 3.0 percent in the medium, and 0.5 percent in the low hazard zone.

A number of additional pines had blister rust infections which, in the opinion of the experienced technicians conducting the survey, would not be fatal. Such cases frequently occur where only the needles in the outer portion of the pine crown have been infected. Before an infection becomes fatal, the canker must progress through the twig and the branch to the trunk where it can girdle the tree. This requires several years, depending mainly on the distance between the initial infection and the tree trunk. In heavy stands infected lower branches

Table 1.--Number of white pines examined and proportion fatally infected by hazard zone and State

Hazard zone and State	Number of pines examined	Percentage of pines fatally infected
High hazard:	14,252	9.2
Minnesota	2,402	12.9
Wisconsin	9,902	8.5
Michigan	1,948	8.1
Medium hazard:	17,885	3.0
Minnesota	11,106	2.9
Wisconsin	6,779	3.1
Low hazard:	13,418	.5
Wisconsin	4,694	1.0
Michigan	8,724	.3
Total	45,555	4.2

and needles frequently die and slough off, thus removing the infection before it can reach the trunk. Infected pines under such circumstances were considered not fatally infected and were counted as healthy trees.

Infection rates during period 1948-52

Comparisons of healthy and infected pines are of little help in evaluating the benefits to be gained by rust control measures, unless the number of new infections originating during a specific period of time is determined. Unless related to time, rust incidence data merely indicate the proportion of standing pines in which rust infections are visible at the time of examination. Infected trees are continually dying and disappearing and recent infections often are not visible and cannot be counted. To determine rates of losses, proportions of pines fatally infected by rust cankers originating during a 5-year period, 1948-52, were determined. A 4-year incubation or development period

prior to the time of examination was allowed so that cankers to be counted could more easily be recognized.

For the region as a whole, 2.5 percent of the 46 thousand pines examined were fatally infected during the 5-year period (table 2). The proportion ranged from 5.8 percent in the high hazard zone of northern Minnesota to 0.2 percent in the low hazard zone of Lower Michigan. It averaged 5.2 percent in the entire high hazard zone, 1.9 percent in the medium, and 0.3 percent in the low hazard zone. Statistical analyses indicated that the differences among zones are highly significant. The differences among States within each zone are not significant.

Table 2.--Proportion of white pines fatally infected during period, 1948-52, by hazard zone and State

(Percent)

Item	High hazard	Medium hazard	Low hazard	All zones
All Lake States:				
Proportion infected	5.2	1.9	0.3	2.5
Sampling error	10	13	20	--
Minnesota:				
Proportion infected	5.8	1.6	--	2.4
Sampling error	30	14	--	--
Wisconsin:				
Proportion infected	5.3	2.4	.6	3.4
Sampling error	10	21	22	--
Michigan:				
Proportion infected	3.8	--	.2	--
Sampling error	27	--	38	--

Infection rates by tree-size class

The proportion of pines infected during 1948-52 was relatively constant for all tree-size classes 1 inch d.b.h. and larger (fig. 2). The infection rate for seedlings less than 1 inch d.b.h. was about one-half of the rates for larger tree-size classes.

Figure 2.--Proportion of pines fatally infected during 1948-52 by tree-size class.

Infection rates for both seedlings and larger trees varied by hazard zones. The proportion of Lake States white pine seedlings less than 1 inch d.b.h. fatally infected during 1948-52 averaged 4.5 percent in the high hazard zone, 1.6 in the medium, and 0.2 in the low (table 3). Corresponding percentages for pines 1 inch d.b.h. and larger were 6.3, 2.8, and 0.6.

This apparent difference in infection rates between seedlings and larger trees was judged misleading and due largely to faulty data. Numerous reasons for this difference were discussed with blister rust specialists and many factors were considered. For example, seedlings have small crowns and therefore present small targets for the airborne rust spores. On the other hand, the crowns of seedlings are near the ground in close proximity to the ribes where spore concentrations may be greatest. While seedlings often are shielded from the spores by high grass, ferns, or brush, such cover may create cool moist shade which favors rust infection. Most seedlings in natural stands are more or

Table 3.--Percentage of white pines fatally infected during 1948-52 by tree-size class and hazard zone

(Percent)

D.b.h. class	High hazard	Medium hazard	Low hazard	Lake States average
Less than 1 inch	4.5	1.6	0.2	1.9
1 inch and larger	6.3	2.8	.6	3.8
Average all sizes	5.2	1.9	0.3	2.5

less suppressed by larger competitors, while the more vigorous dominant pines are believed to be most susceptible to blister rust. The survey was conducted in late fall and snow might have obscured infections on lower branches of seedlings examined. Some of the seedlings included in the tally probably were less than 9 years of age. Such seedlings did not exist and therefore were not exposed throughout the entire 5-year infection period, which obviously would reduce the apparent 5-year rate of infection for all seedlings. Finally and most important, small seedlings can die and disintegrate within a very few years following infection. Undoubtedly many small seedlings infected during 1948-52 had died and disappeared by 1956. It was concluded that the seedling data were unreliable and that estimates of rust infection losses should be based only upon data pertaining to pines 1 inch d.b.h. and larger.

Relationship of ribes population to rust infection rate

Study results indicate that, beyond a relatively few bushes per acre, ribes population has little effect on fatal blister rust infection rates. Since all areas sampled had been recently treated, none were under control at the time to which these data apply. The number of ribes bushes on sample areas ranged from very few up to 200 per acre, with a few areas as high as 700 per acre. No significant differences in fatal infection rates were evident among areas of different ribes populations. Apparently very low ribes populations can cause large losses in localities of high hazard. Studies and experience of rust control specialists have shown that ribes populations as low as 20

feet of live stem[4] per acre cannot be tolerated in many Lake States problem areas. The critical amount, of course, depends on the distribution as well as amount of live stem per acre and on weather conditions. Measurements made in this study were not precise enough to determine critical population levels. Results do indicate, however, that complete or practically complete eradication of ribes is essential to establish control of blister rust in areas of high hazard.

Little if any benefit apparently is gained by partial control measures. Infection rates were computed separately for untreated areas and areas previously worked but not under control to determine the effects of partial control. About 340 sample plots were on untreated areas and 180 were on areas which had been given ribes eradication treatment one or more times, but were not considered under control. The small difference in infection rates between the two types of areas was not significant. This is a further indication that small ribes populations might be as dangerous as heavy ribes concentrations, and emphasizes the need for thorough eradication of ribes on control areas.

Possible reduction in losses by pruning

About one-third of the fatally infected pines could be saved by pruning off the infected branches, according to the judgment of the experienced fieldmen who conducted the survey. Each fatally infected pine tallied was classified as prunable or unprunable. If no portion of the canker could be seen within 5 inches of the trunk, the infected tree was considered prunable. The proportion of fatally infected pines that could be saved by pruning averaged 37 percent in the high hazard zone, 29 percent in the medium, 26 percent in the low, and 34 percent in all zones combined.

Other variables considered

The effects of density of pine stocking and of general weather conditions on infection rates also were considered in an attempt to further refine the rust infection data.

4/ Live stem refers to the living stem and branches of ribes plants measured in lineal feet as though all the branches were torn apart and placed end to end.

Density of pines on the sample areas varied from about 100 to 1,500 stems per acre. In dense stands some pines possibly are shielded from the air-borne rust spores by other trees. On the other hand, moisture conditions and the greater number of targets for rust spores in dense stands probably favor infection. The percentage of pines infected did not vary significantly among stands of different densities up to the maximum encountered of 1,500 per acre.

Blister rust technicians agree that cool moist weather, particularly during the late summer months, tends to increase rust infection rates in pine. Dry warm weather reduces rust sporulation and causes the delicate sporidia to lose viability thus reducing the pine-infecting potentialities of the fungus. Rough comparisons of the incidence of rust infections originating from year to year, as determined in this study, and of related weather conditions support this belief. The numbers of rust cankers originating during each of the cool wet years 1950 and 1951 were two to three times the numbers originating during the warmer and drier years preceding and following.

CONCLUSIONS

How important is the impact of blister rust losses in the commercial production of eastern white pine on unprotected areas? That obviously varies by localities and depends upon the density and spacing of pines in initial stands as well as upon local rust infection and mortality rates.

In the low-hazard zone, an average 5-year loss of 0.6 percent of the pines causes relatively little pine volume loss for the region as a whole. Much higher rates on individual properties, however, cause serious local problems.

In the high-hazard zone, rust losses averaged 6.3 percent for 5 years, or 1.26 percent of the remaining healthy pines each year. If this rate were maintained throughout a rotation of 100 years, only 29 percent of the trees in the initial stand would escape fatal infection. However, some trees killed by rust after reaching merchantable size could be salvaged. Furthermore, pines infected after reaching sawtimber size generally continue to live and grow for long periods before dying. As much as 20 years might elapse between initial infection and girdling of sawtimber trees. Dominant pines on medium Lake States sites normally average about 13 inches d.b.h. at 80 years of age. Infections originating after a stand has reached 80 years, therefore, will have little effect on volume or value of yield at rotation age 100.

Accordingly an estimate of probable loss to blister rust during a 100-year rotation can be computed by applying the annual rate of infection up to age 80. The loss thus computed for the high hazard zone is 63 percent of original stocking, with 37 percent of the initial stand surviving. Similar estimates of the percentages of present stands of different ages that will survive rust infection during a 100-year rotation are presented by hazard zones in table 4.

Table 4.--Estimated proportion of present unprotected white pine stand that will survive blister rust infection during 100-year rotation by present age of stand and hazard zone.

(Percent)

Present age of stand (years)	High hazard	Medium hazard	Low hazard
5	39	66	92
10	42	68	92
15	44	70	93
20	47	72	93
25	50	74	94
30	54	76	94
35	57	78	95
40	61	80	96
45	65	82	96
50	69	85	97
55	73	87	97
60	78	89	98
65	83	92	98
70	88	95	99
75	94	97	99
80	100	100	100

In some stands with well-spaced and heavy initial stocking, losses as great as indicated for the high hazard zone might not be serious, and in certain cases might even provide beneficial thinning. Unfortunately, however, white pine stands in the Lake States generally are not heavily stocked. Pine stocking on the sample plots in this study averaged about 300 stems per acre, and even the youngest stands seldom exceeded 1,500 per acre. Another unfavorable factor is the tendency of blister rust losses to be concentrated in the more vigorous dominant pines which could increase the proportion of slow-growing, suppressed trees in the remaining uninfected stand. With light pine stocking,

rust-caused mortality of almost two-thirds of the initial stand undoubtedly would be very serious.

Complete evaluation of the impact of blister rust losses involves consideration of various combinations of site, stocking, rust hazard, and control costs, and of the costs and benefits to be gained by control of other forest pests and by alternative management measures which affect growth rates and ultimate stand yields. This must await completion of the more comprehensive analysis of the economics of eastern white pine production.

SOME RECENT STATION PAPERS

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- Tamarack, by Eugene I. Roe. Sta. Paper 52, 22 pp., illus. 1957.
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